

# Chapter III: THE PROCESS OF INVENTION AND INNOVATION—MARCONI AND THE WIRELESS TELEGRAPH: 1896–1920

*Marconi was eminently utilitarian. His predominant interest was not in purely scientific knowledge *per se*, but in its practical application for useful purposes.—SIR AMBROSE FLEMING.*

THE scientific pioneers of wireless—Maxwell, Hertz and Lodge<sup>1</sup>—were university scientists working in an environment where the goals were largely non-commercial. There is a strong similarity between personal dedication to science and dedication of one's life to the church; as in the church, a cardinal or a bishop may have both materialistic and spiritual interests, so in science a professor may develop the commercial application of his work. But usually, the major goal of the university professor has been contribution to pure science. And this desire has been re-enforced in modern times by the growing importance of professional pride and professional recognition.

The strength of this tradition can be observed today in the lives of our senior physicists—Einstein, Niels Bohr, Fermi, etc.—whose motivation has been the creative intellectual urge to extend the boundaries of our understanding of Nature. The application of

<sup>1</sup> In focussing attention on Maxwell, Hertz and Lodge, and later Marconi, de Forest and Fessenden, I do not wish to build up the heroic theory of invention. Science and invention rarely progress in discontinuous spurts. On the other hand the process of invention and innovation is comprised of the sum total of the work of many *individuals*, each of whom has the opportunity during his lifetime of maximizing or minimizing his own creative response to his environment. I believe that the economic problems confronting Marconi, de Forest and Fessenden, and the way in which they responded, were typical of the period in which they operated.

these advances, except under the special pressure of wartime service, they have left entirely to others.

In the story of the process of technological development in the radio industry, there was a clear-cut division of labor between the university physicist and the inventor who came later. The university scientists were not interested in inventions or in patents. Hertz had no intuitive conception of the commercial possibilities of wireless. Had he had such a conception, the tradition of pure science would have been against his taking out patents.<sup>2</sup> Michael Faraday designed the first electric motors and dynamos, but he never applied for a patent. By contrast, Marconi, who was almost exclusively interested in making wireless work, applied for patents on everything that he did.

### *1. Marconi, the Innovator*

Guglielmo Marconi was not a highly trained scientist.<sup>3</sup> Educated in Italy primarily by tutors, Marconi early developed an absorbing interest in physics and chemistry. When he was twenty (1894), he read for the first time in an Italian electrical journal of the work and experiments of Hertz.<sup>4</sup> Marconi's imagination was stirred by the possibility of making wireless communication a practical reality. Two large rooms at the top of his parents' villa were set aside for experiments, and there young Marconi worked almost constantly on perfecting home-made radio equipment. He improved on the Hertzian oscillator by constructing transmitting apparatus which, from an elevated aerial, discharged

<sup>2</sup> The tradition persists today. Dr. Rabi, in his recent testimony on science legislation, declares: "University scientists in general are not patent-minded. At Columbia University the policy has been that anyone can patent whatever he pleases, and even though the research has been supported by the university, the university makes no claim on that patent. Very few have availed themselves of this privilege. A patent-minded colleague in our department would in time find that he has few scientific friends. We like to discuss matters freely, and it gives us the jitters to feel that someone is going to rush off and patent some idea which came up." Senate Sub-Committee on War Mobilization, Hearings on Kilgore and Magnusson Bills, 1945, p. 976.

<sup>3</sup> Sir Ambrose Fleming, "Guglielmo Marconi and the Development of Radio Communication," *Journal of the Royal Society of Arts*, Nov. 26, 1937, p. 57.

<sup>4</sup> B. L. Jacot and D. M. B. Collier, *Marconi, Master of Space* (London, Hutchinson, 1935), p. 24.

across a spark gap to earth.<sup>5</sup> He also improved on Lodge's coherer by choosing the metal more carefully, grading the plugs and evacuating the tube.<sup>6</sup> By the beginning of 1896 Marconi was receiving Morse code messages over a distance of nearly two miles.<sup>7</sup>

As Marconi's family had wealth, there was no practical necessity for him to earn a living. He was swept into wireless experimentation with an irresistible inner compulsion, and his persistence, to the exclusion of almost all other interests, was perhaps the principal reason for his outstanding success. His career bears out a conclusion of Benjamin Franklin:

I have always thought that a man of tolerable abilities may work great changes, and accomplish great affairs among mankind, if he first forms a good plan, and, cutting off all amusements or other employments that would divert his attention, makes the execution of that same plan his sole study and business.

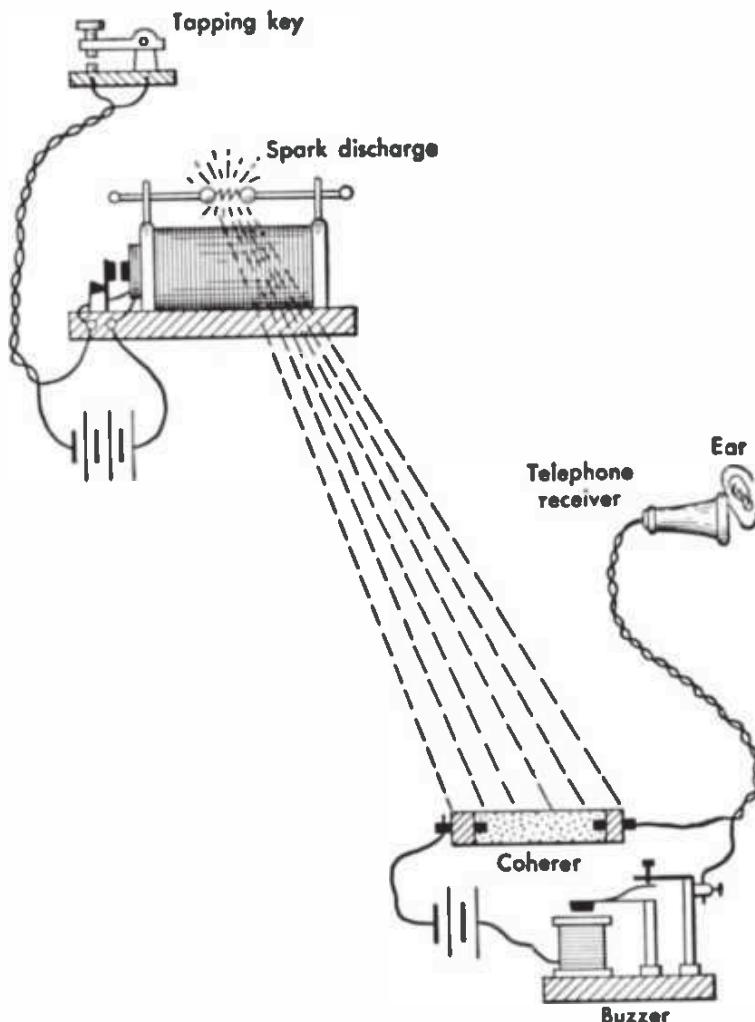
Marconi was also greatly aided by his family connections. His mother was of the Irish aristocracy and moved in the "best circles" in England. The family concluded that Guglielmo would have a better chance to commercialize his inventions there than in Italy. A visit was arranged in 1896, and the young inventor (then twenty-two) was introduced to government officials and capitalists who might be interested in the radio field. Among these officials was William Preece, engineer-in-chief of the British Post Office. Preece himself was an inventor of distinction who had worked on inductive wireless telegraphy.<sup>8</sup> He took a keen interest in Marconi, and planned a demonstration for the post office engineers. Marconi, who had been steadily improving the

<sup>5</sup> Sir Oliver Lodge has commented on this discovery in the following terms: "His (Marconi's) novelty was that he employed a high aerial and an earth connection as the effective radiator. In the achievement of actual telegraphy the earth connection was an assistance; but in my experiments on the demonstration of the waves I had avoided earth connection (1894) as giving an unfair advantage from the point of view of theory. If a disturbance was detected through the earth that wasn't the same thing as detecting it through waves in space. But for practical telegraphy, any and every method was legitimate; and no one now had any serious doubt about the waves." *Past Years, An Autobiography*, *op. cit.*, pp. 232-233.

<sup>6</sup> Eccles, *op. cit.*, p. 61.

<sup>7</sup> The reader who is not familiar with the way in which wireless operates may wish to refer to Appendix I at this point as background for subsequent discussion.

<sup>8</sup> Preece had succeeded in telegraphing by induction a distance of four and one-half miles.



Representation of the fundamental features of wireless signalling, showing the spark gap of an induction coil which can be switched on and off by a tapping key in the circuit. Oscillatory currents from the spark gap excite the coherer, causing it to become a good conductor. If the coherer is placed in series with a battery and a telephone receiver, it will switch the current in the telephone on and off in synchronization with the tapping key of the transmitter. The coherer may also be used to actuate recording mechanisms. (Courtesy, Horrabin, illustrator. Reprinted from *Science for the Citizen*, by Lancelot Hogben, by permission of W. W. Norton & Company, Inc. Copyright 1944 by the publishers.)

workmanship of every part of his equipment, showed that messages could be sent up to eight miles. This success and the interest displayed by Preece led to the formation of the British Marconi company in 1897.

Two years later an American subsidiary was launched. From then until the formation of the Radio Corporation of America

in 1919, the Marconi companies were the dominant concerns in British and American wireless.

The original capital of the British Marconi company ( £100,000) was subscribed largely by wealthy individuals who wanted a speculative investment in the new wireless venture. The company had a distinguished directorate; and, considering the fact that Marconi himself was only twenty-three at the time, the terms were exceptionally favorable. Marconi obtained £15,000 in cash and 60 per cent of the original stock in exchange for almost all of his patent rights.<sup>9</sup>

#### (a) EXPERIMENTS WITH LONG-DISTANCE COMMUNICATIONS

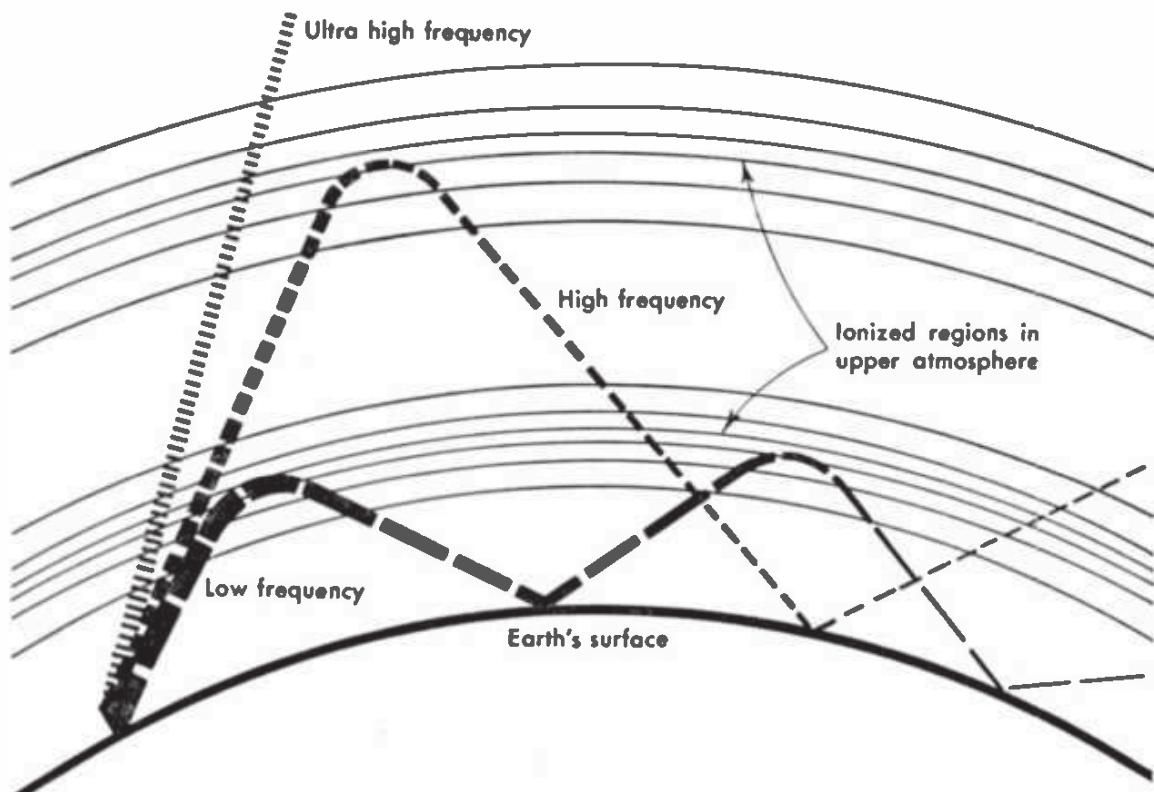
The ease with which the company was launched reflected the public interest in the new electrical developments emerging on every hand. Here was a young inventor, Marconi, who had already succeeded in sending messages eight miles. Wasn't this case likely to be comparable to the telephone? Wasn't wireless going to absorb most of the lucrative transmarine cable business in a few years? Marconi assured investors that it would.<sup>10</sup>

The technical obstacles to the commercial transmission of wireless messages proved much more difficult than Marconi anticipated. Here the analogy with the telephone proved fallacious. Wireless did not become profitable until the difficulties of long-distance communication were overcome; while in the telephone industry substantial profits were earned many years before long-distance telephony became a reality. The early investors in wireless, therefore, were doomed to disappointment. The British Marconi company did not pay dividends from 1897 to 1910.

Immediately after his company was formed, Marconi began experimenting with long-distance communications. The scientists

<sup>9</sup> He reserved to himself his patents in Italy and her dependencies. Marconi testimony, *Marconi Wireless Telegraph Company of America vs. De Forest Radio Telephone and Telegraph Company, U.S.D.C., S.D.N.Y., in Equity 8211.*

<sup>10</sup> He gave his reasons to a representative of Dow, Jones and Company in 1903: whereas a transatlantic cable cost \$4,000,000, with an annual maintenance and operating cost of \$400,000, the cost of installing a wireless station capable of doing the same amount of business would be only \$200,000, with yearly costs of \$50,000. "Estimating the present average at but ten words per minute, and the average price of transmission but seven cents per word, the revenue would be \$42 per hour, or \$1,008 per day, or over \$365,000 per year for each station." *Electrical World*, Feb. 28, 1903, p. 361.



Representation of the methods in which radio waves are propagated. Ionized layers of the atmosphere reflect the waves back to earth, the area of return differing with the frequencies used. (Courtesy Dunning and Paxton, *Matter, Energy, and Radiation*, McGraw-Hill)

of the day did not agree on how electro-magnetic waves were conducted around the earth's surface. Nikola Tesla declared as early as 1893 that the upper strata of atmosphere (today called the ionosphere) were conductive and that waves could be sent long distances in the narrow space between the surface of the globe and the conducting strata.<sup>11</sup> But Tesla's actual experiments in long-distance transmission proved a failure. And many scientists believed that wireless waves behaved like light waves and that one could not hope for greater distance than could be achieved by diffraction.

<sup>11</sup> Eccles, *op. cit.*, p. 76. The scientific theories for this phenomenon were later expounded by Oliver Heaviside and A. E. Kennelly, in whose honor the reflecting layer is named the Kennelly-Heaviside Layer. In 1902 Heaviside, writing in the tenth edition of the *Encyclopedia Britannica*, said: "The irregularities make confusion, no doubt, but the main waves are pulled round by the curvature of the earth, and do not jump off. There is another consideration. There may possibly be a sufficiently conducting layer in the upper air. If so, the waves will, so to speak, catch on to it more or less. Then the guidance will be by the sea on one side and the upper layer on the other."

Marconi, nevertheless, decided to erect an experimental station in England and one in Newfoundland, 1,700 miles away.<sup>12</sup> On December 6, 1901, Marconi landed in Newfoundland, to determine whether he could receive a wireless signal transmitted across the Atlantic Ocean. His receiving station was on a high bluff beside the ocean. On the twelfth of December he flew a kite with wires connecting it to the receiving station, and was able to hear faintly a signal of the Morse telegraphic letter "S" transmitted from England.<sup>13</sup>

Despite this initial success and the excellent backing that Marconi received, the Marconi enterprises were to go through a very trying period. The company soon began to feel the opposition of the vested interests in the cable and the telegraph lines. When Marconi started to erect a permanent receiving station in Newfoundland, the Anglo-American Telegraph Company, whose cables terminated there, contended that such action violated its franchise.<sup>14</sup> Marconi finally succeeded in persuading the Dominion Government of Canada to give him a franchise and to appropriate £16,000 for the erection of a station at Glace Bay.<sup>15</sup> This was done only after Marconi promised wireless telegraph rates from England to Canada of 10 cents a word, compared with 25 cents for the cable.<sup>16</sup>

The opposition of the British Post Office also had to be overcome. Although William Preece had been very encouraging to Marconi, Austen Chamberlain, as Postmaster-General, took quite a different attitude. He saw the Marconi company as a potential competitor of the government-controlled telegraph industry, and adamantly refused to connect the Marconi overseas service with the post office telegraph lines. If someone in London wished to send a Marconigram to Paris, he had to go to a local Marconi office; the office would send a messenger to the post office to telegraph the Marconi broadcasting station in Dover. The message was then relayed across the Channel and sent to its final destination through the French telegraph offices—in all, a slow and ex-

<sup>12</sup> Jacot and Collier, *op. cit.*, p. 68.

<sup>13</sup> R. N. Vyvyan, *Wireless over Thirty Years* (London, Routledge, 1933), p. 29.

<sup>14</sup> *Ibid.*, p. 31.

<sup>15</sup> *Ibid.*

<sup>16</sup> *Electrical World*, March 29, 1902, pp. 543-544.

pensive procedure. The cross-channel cable companies, by contrast, had a direct connection with the post office.<sup>17</sup> Marconi could compete only by substantial rate cutting; and, as wireless was much more subject to interruption by atmospheric conditions than the cable, the volume of traffic remained small.

#### (b) DEVELOPMENT OF SHIP COMMUNICATIONS

Marconi soon realized that his company would not survive if it relied primarily on international communications. The most promising field for immediate exploitation seemed to be communication with ships.

Marconi's plans for marine wireless were large and ambitious. He hoped to control the basic patents in the art, and to equip ships of all nations with wireless apparatus. He hoped also to erect shore stations at key points around the world, through which all ship messages would be sent. In the pursuit of these objectives, Marconi was determined to obtain a monopolistic position. Although he succeeded, his aggressive tactics created great antagonism.

Two important ship contracts were secured at the outset—one with Lloyd's and one with the British Admiralty. The Lloyd's contract called for the erection of a series of wireless stations on the coast of England, and the Admiralty contract, for the equipping of thirty-two ships of the British fleet with Marconi apparatus.<sup>18</sup> Lloyd's agreed that for a period of fourteen years from 1901, Marconi apparatus would be used exclusively in equipping the ships it insured.<sup>19</sup> But the Marconi management was too grasping, and Lloyd's brought suit over the interpretation of the contract. Lloyd's contended that the Marconi company had refused to equip its shore stations if these were in the same locality as Marconi installations. Marconi lost the case. In a new contract,

<sup>17</sup> An agreement between the post office and the Marconi company was finally signed on August 11, 1904, by which the Postmaster-General undertook to give facilities for wireless telegraphic traffic. Testimony, H. B. Smith, *Report to Select Committee on Radiotelegraphic Convention*, House of Commons (London, H. M. Stationery Office, 1907), p. 7.

<sup>18</sup> The Admiralty paid £20,000 down, £1,600 for each of 32 installations and £5,000 yearly during continuation of agreement, for a period of eleven years beginning in 1903. Testimony, Col. Daniell, Assistant Director of Naval Intelligence, *Report to Select Committee, op. cit.*, p. 50.

<sup>19</sup> *Electrical World*, Nov. 9, 1901, pp. 785–786.

signed in 1905, these points of difference were resolved and both firms agreed to use their "best endeavors" to induce British and foreign governments to grant no wireless licenses to any companies except Lloyd's and Marconi.

Marconi had decided in 1900 that he would not sell apparatus outright, but only lease it.<sup>20</sup> This decision covered all types of wireless equipment. When Fleming wrote Marconi to ask if his valve could be put on sale, Marconi replied:

.... your valve is likely to become a very valuable receiver for long distance wireless, and I wish if possible to keep the monopoly of these experiments to ourselves.<sup>21</sup>

Marconi's leasing arrangements to ships provided for a certain number of messages per month without charge, plus a standard rate per word above this maximum. The company trained and furnished wireless operators who remained on the Marconi payroll. Marconi reasoned that, if the equipment were sold outright, the price charged could not be large enough to support any effective research and engineering. And he was determined to perfect his system of radio communications by continuing his experiments.

Competition, however, developed from Germany and from the United States. The Germans were engaged in a commercial struggle to break into international markets on equal terms with the British and were anxious to challenge the incipient Marconi monopoly. Marconi had applied for and obtained patents on his inventions in Germany; but the Germans developed through the Telefunken Corporation a rival system to Marconi's based on the inventions of Professor Ferdinand Braun, Dr. Rudolf Slaby and Count George von Arco.<sup>22</sup> Shore stations were erected in Ger-

<sup>20</sup> An exception was made in the case of the British Navy which insisted on purchase.

<sup>21</sup> Fleming deposition, *Marconi Wireless Telegraph Company of America vs. De Forest Radio Telephone and Telegraph Company*, *op. cit.*, p. 127.

<sup>22</sup> Prior to 1903 the Braun-Siemens and Halske system had been developed by the Gesellschaft für Drahtlose Telegraphie, while Slaby-Arco was the system of the Allgemeine Electricitäts-Gesellschaft. The patents of the two groups came into conflict in the courts; and on May 30, 1902, a Berlin court handed down a decision for Braun and Siemens and Halske. The Kaiser ordered a halt to the rivalry, and accordingly the two systems were amalgamated in 1903 under Gesellschaft für Drahtlose Telegraphie, known as the Telefunken System.

many; and key ships of the German Navy were equipped with Telefunken apparatus. An American subsidiary was established in 1905 with a powerful station in New York City.<sup>23</sup> In addition, the parent company manufactured and sold transmitting and receiving apparatus noted for high quality.

In the United States the American De Forest Wireless Telegraph Company and its successor, United Wireless,<sup>24</sup> began to invade Marconi's market by leasing and selling radio apparatus at a price that was considerably cheaper than the Marconi arrangements.

Marconi found himself compelled to sell rather than lease wireless apparatus to the navies of various countries, but he retained numerous restrictions. A navy had to pay a substantial flat royalty each year; equipment was to be purchased at current market prices, including duty; messages must be accepted for relay from Marconi-equipped merchant vessels and commercial Marconi stations; and Marconi equipment was not to be used for communication with any rival system except in an emergency or when working with another naval vessel. In return, the navy was granted certain privileges at Marconi stations in the way of rates, time, etc., that would make unnecessary the building of many expensive shore stations of its own.<sup>25</sup>

Marconi had a sufficient head-start over his rivals so that several navies signed such contracts. The American Navy, however, refused to make any such agreements, and insisted that all apparatus be purchased by competitive bidding. Since at first the Marconi company would not agree to this, the United States Navy turned to German companies—Slaby-Arco and Telefunken—and to American companies such as De Forest, for its wireless apparatus.

Merchant shipping companies in many cases would also have preferred outright purchase of Telefunken or De Forest equipment. But here the Marconi company remained at a substantial advantage over its competitors, since English stations all over the world refused to communicate with ships having other than Mar-

<sup>23</sup> *Electrical World*, Dec. 9, 1905, p. 1005.

<sup>24</sup> This will be described in detail in the next chapter.

<sup>25</sup> Paul Schubert, *The Electric Word* (New York, Macmillan, 1928), pp. 33–34.

coni equipment. This policy aroused so much antagonism that it ultimately had to be changed. In 1903 the German government called a special international wireless conference in Berlin at which Germany proposed that coastal stations be required to accept messages regardless of their system of origin. The Marconi strongholds, England and Italy, steadfastly opposed this; and, although a Convention was drawn up, it lacked ratification by a sufficient number of governments to make it significant.

Five years later, as a result of constant agitation, international coastal stations were opened to all senders.<sup>26</sup> The British Marconi company acquiesced only after the British government agreed to make good by a three-year subsidy any loss the company might suffer as a consequence of the new plan.

Despite the aggressive nature of Marconi's campaign to control ship-to-shore communications, his companies remained in financial difficulties until about 1910. Wireless was still regarded as a luxury for most ships and the volume of traffic was scarcely sufficient to yield a return on the large capital investment involved. The sinking of the *Republic* in 1909 and the *Titanic* in 1912 brought dramatic attention to the practical importance of wireless for safety of life at sea. The *Carpathia*, which responded to the *Titanic*'s SOS signal and rescued 700 survivors, was 58 miles away and did not reach the scene for several hours. Later it was discovered that a "dead ship"—a freighter without wireless—had passed within 25 miles at the time the *Titanic* sank, and that the *California* was less than 20 miles away but her wireless operator had retired for the night. The public was aroused; and from 1910 to 1912 laws were passed in the United States,<sup>27</sup> England and other maritime countries requiring all ships above a certain size to carry wireless.

<sup>26</sup> July 1, 1908.

<sup>27</sup> In the United States, the Radio Act of 1910 had made it unlawful, after July 1, 1911, for any passenger vessel carrying 50 or more persons, including passengers and crew, plying between ports more than 200 miles apart, to leave any port in the United States unless equipped with "an efficient apparatus for radio communication, in good working order" with a skilled operator in attendance. Following the *Titanic* disaster, the 1910 Act was amended to require two operators and a constant watch, as well as an auxiliary source of power capable of operating the wireless for four hours. In addition, the scope of the Act was extended to cover cargo vessels.

This legislation gave a substantial boost to radio. The position of the Marconi company was also materially strengthened by the fact that its principal American rival—United Wireless—went into bankruptcy in 1912, and its assets were acquired by the British and American Marconi companies. A contributing factor to the bankruptcy was that United Wireless was found guilty of infringing the Marconi “four sevens” patent and the Lodge tuning patent.<sup>28</sup> American Marconi thus gained control of the 400 ship installations and 17 land stations belonging to its competitor. This gave it almost “all the coast stations of importance on the Atlantic and Pacific coasts, besides practically the whole of the American Mercantile Marine at present fitted with wireless installation.”<sup>29</sup> The result was that the company carried on about 90 per cent of the American ship-to-shore business between 1912 and the outbreak of war in 1917.<sup>30</sup>

Immediately after acquiring United Wireless, American Marconi increased its minimum charge for merchant ships to \$1,000 a year, claiming that the previous charges had “not satisfactorily recompensed the company for the work and labor entailed in operating the stations. . . . It is impossible for the company to do business profitably at the low rates hitherto prevailing.”<sup>31</sup> From this time on, the company began to enjoy increasing prosperity.

As may be seen from the following table and chart, it thus took many years for Marconi’s wireless innovations to develop into a profitable and secure system of interlocking companies handling ship-to-shore communications over a large portion of the world.

<sup>28</sup> See Annual Report of the American Marconi company for the Year Ending January 31, 1912, pp. 4–5.

<sup>29</sup> Annual Report, 1913, p. 5.

<sup>30</sup> Testimony of Vice-President Nally in 1918 before the Committee on Merchant Marine and Fisheries in the House hearings held on HR13159 for government control of radio.

<sup>31</sup> Annual Report, 1914. The new arrangements were as follows: the contract allowed the shipowners 6,000 words per year to Marconi coastal stations without charge, above which regular coastal rates would be paid. The company furnished the operators, and the shipowner paid their wages and maintenance. The company also maintained the apparatus and added improvements to the ship sets as they were developed. Testimony of Sarnoff on HR13159.

TABLE I: MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA  
INCOME AND EXPENSES  
1903-1918

Year Ending	Organization Expenses and Deficit Acct.	Net In- come after Taxes	Depreciation and Reserves	Net Profit
Jan. 31, 1903	\$ 35,468	Deficit	—	—
Jan. 31, 1904	85,183	Deficit	—	—
Jan. 31, 1905	168,843	Deficit	—	—
Jan. 31, 1906	257,475	Deficit	—	—
Jan. 31, 1907	384,804	Deficit	—	—
Jan. 31, 1908	422,422	Deficit	—	—
Jan. 31, 1909	448,803	Deficit	—	—
Jan. 31, 1910	+45,102*	\$ 16,637	\$ 12,936	\$ 3,701
Jan. 31, 1911	—	9,405	11,126	1,721(d)
Jan. 31, 1912	—	26,499	11,261	15,238
Jan. 31, 1913	—	242,235	30,989	211,246
Dec. 31, 1913†	—	211,484	33,233	178,251
Dec. 31, 1914	—	271,889	122,011	149,877
Dec. 31, 1915	—	288,995	111,678	177,317
Dec. 31, 1916	—	336,041	76,152	259,889
Dec. 31, 1917	—	780,592	162,820	617,773
Dec. 31, 1918	—	897,325	286,516	711,842‡

\* The cumulative deficit was written off in 1911 and 1912.

† For 11 months.

‡ Includes \$101,033 described as "other income."

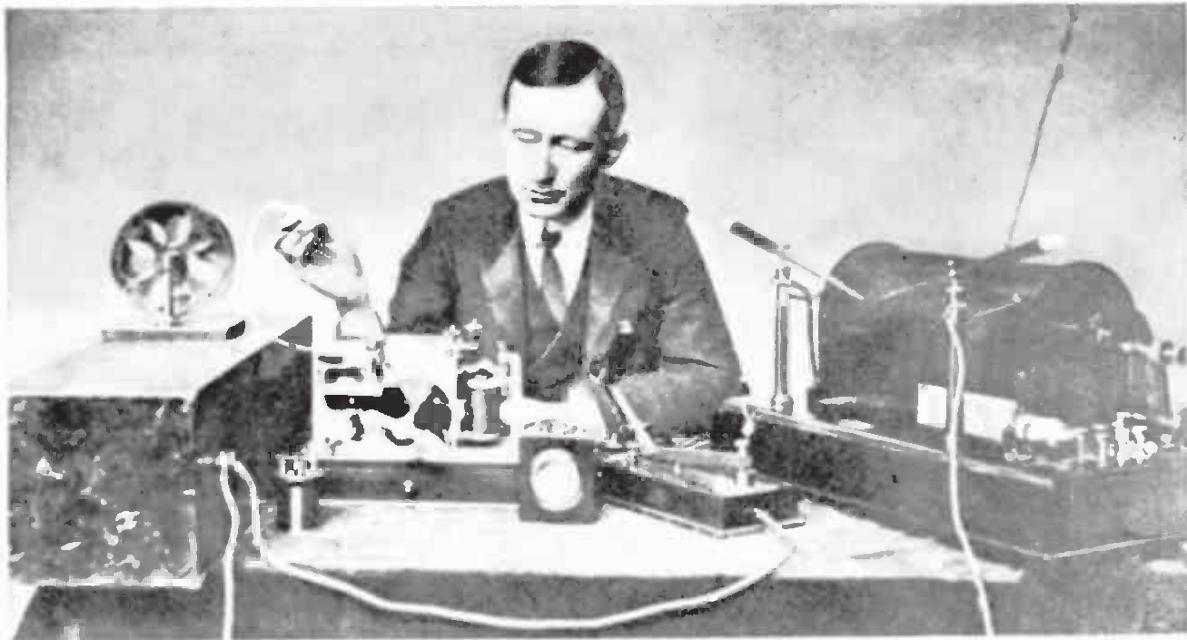
Source: Annual Reports, Marconi Wireless Telegraph Company of America.

## 2. *Marconi, the Inventor*

Professor Ambrose Fleming, who joined the Marconi research staff in 1899, has described the inventor in the following terms:

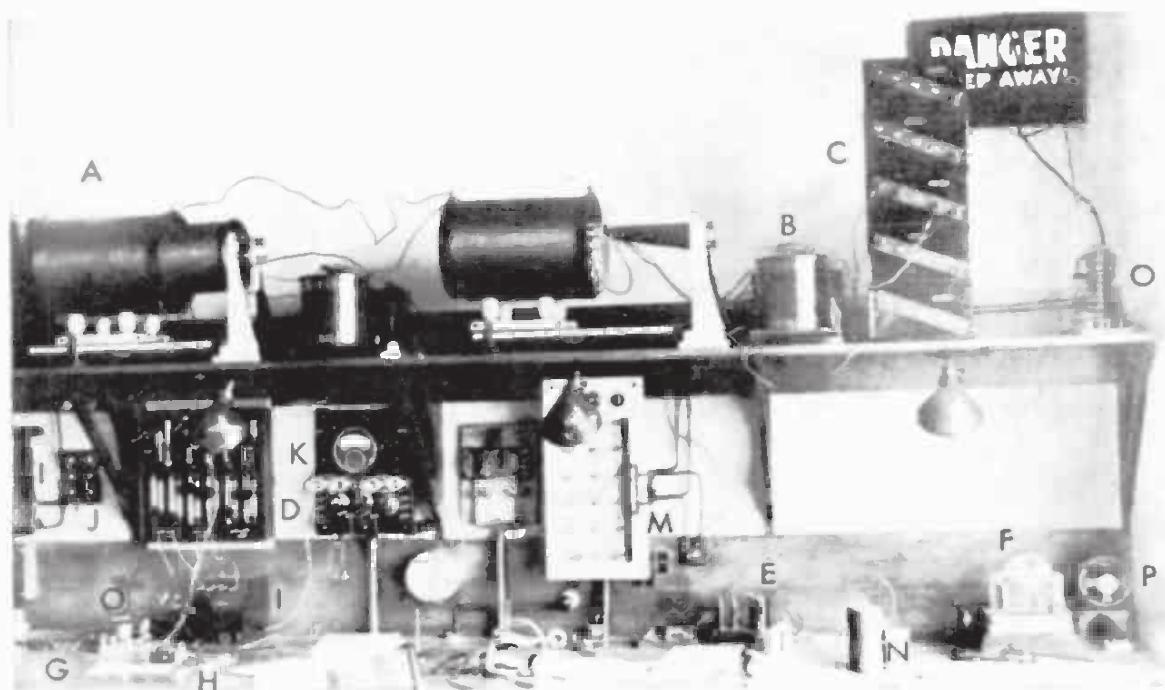
In the first place, he was eminently utilitarian. His predominant interest was not in purely scientific knowledge *per se*, but in its practical application for useful purposes. He had a very keen appreciation of the subjects on which it was worth while to expend labour in the above respect. . . .

He had enormous perseverance and powers of work. He was not discouraged by initial failures or adverse criticisms of his work. He had great power of influencing others to assist him in the ends he had in view. He had remarkable gifts of invention and ready insight into



Marconi with receiving apparatus, approximately 1898. (Courtesy G. H. Clark Radio Collection)

Receiving and control apparatus used in Marconi high-power station at Bolinas, California, for transpacific working with Hawaii and Japan, about 1912. (Courtesy G. H. Clark Radio Collection) A. Coupler; B. Variable condenser; C. Inductance coils in wooden boxes; D. Balanced crystal system; E. Brown relay; F. Wheatstone transmitter; G. Variable condenser; I. Battery box; J. Switch; K. Charging panel; L. Power control switch; M. Transfer switch (to either of two receivers); N. Test buzzer; O. Antenna switch; P. Motor for Wheatstone transmitter.





Marconi station at Poldhu, Wales, 1900, from which first signals were received in Newfoundland. (Courtesy G. H. Clark Radio Collection)

Marconi at transatlantic station at Glace Bay, Canada, about 1903.  
(Courtesy G. H. Clark Radio Collection)

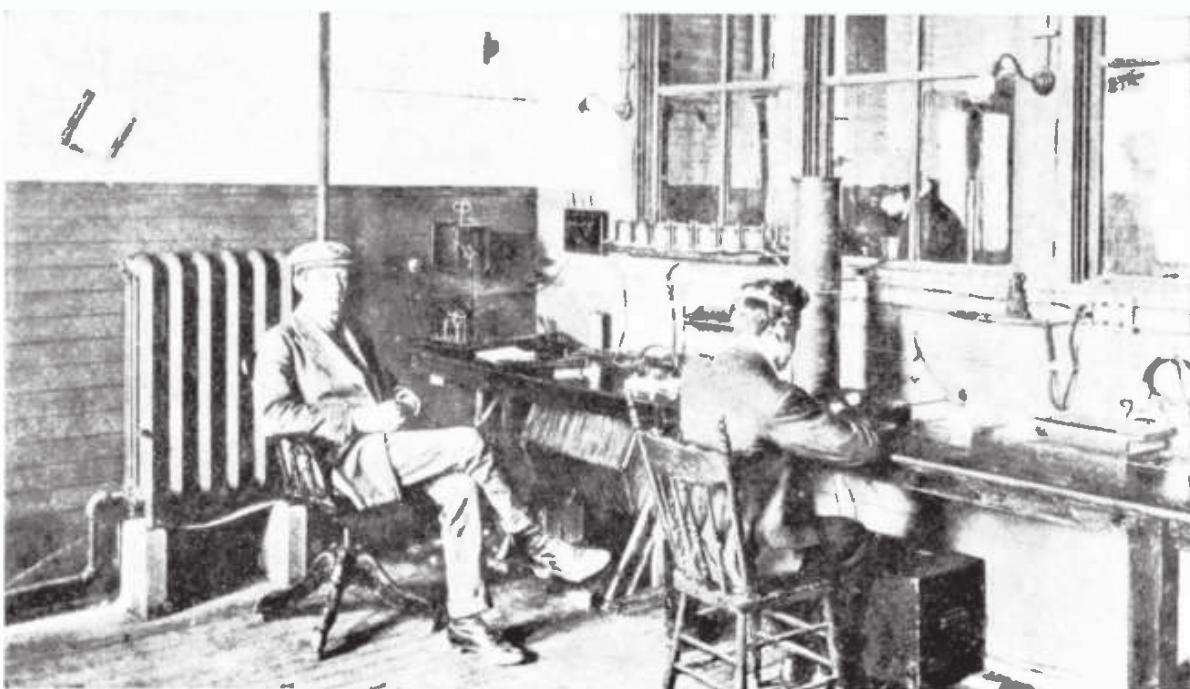
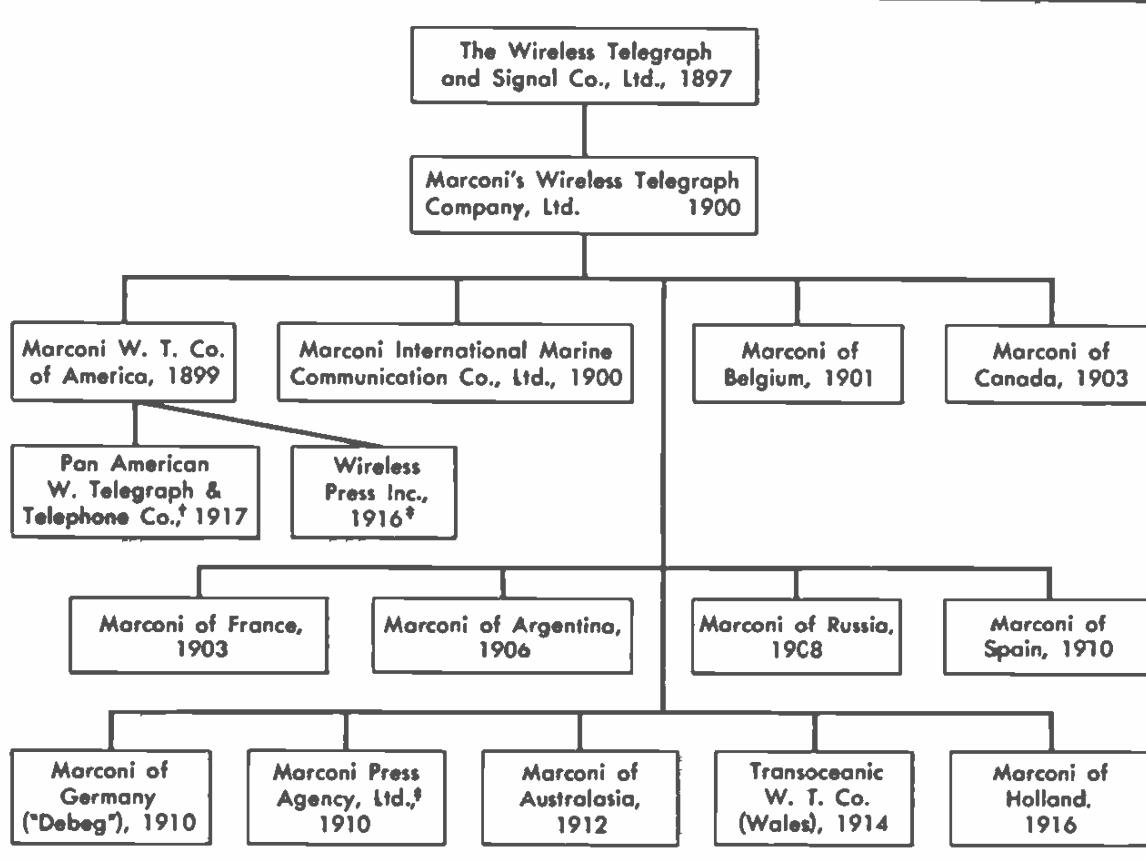


TABLE II  
PRINCIPAL MARCONI ENTERPRISES \*  
1897–1917



\* In a number of foreign subsidiaries, the full titles are not given.

† This was organized jointly by British Marconi, American Marconi, and Federal Telegraph, to develop radio communication in South America.

‡ These subsidiaries operated a general printing and publishing business for wireless books and periodicals.

the causes of failure and means of remedy. He was also of equable temperament and never seemed to give way to impatience or anger, but he did not suffer fools gladly or continue to employ incompetent men. He also owed a good deal to the loyal and efficient work of those who assisted him.<sup>32</sup>

Marconi's contributions to the commercialization of wireless made him more important as an innovator than as an inventor. But his company succeeded in getting possession of many of the principal patents in the radio art, despite the fact that the most important wireless discoveries and inventions were not made by

<sup>32</sup> *Journal of the Royal Society of Arts*, Nov. 26, 1937, pp. 57–62.

him or his associates. Hertz was the first man to produce wireless waves experimentally; Lodge invented selective tuning; Edison first noted the phenomenon associated with electron emission from heated filaments, and Thomson and Richardson explained it theoretically; de Forest through his invention of the triode showed how to control the flow of electrons; Langmuir and Arnold developed the high-vacuum tube; Dunwoody and Pickard produced the first crystal detectors; Tesla pioneered in continuous-wave transmission; Poulsen invented the high-frequency transmitting arc; Fessenden and Alexanderson perfected the high-frequency alternator; de Forest and Armstrong invented the regenerative circuit.

Yet the Marconi company acquired, in wireless patents, a dominant position which far exceeded any of its rivals. Although Marconi's own technical contributions were not revolutionary, he applied for patents on everything that he did; and he was the first worker in the field whose interest was in *practical* wireless telegraphy. The principal patents in Marconi's name were on improved types of vertical antennas, on the improved coherer, on the magnetic detector and on methods of selective tuning. The patents on the coherer illustrate the way Marconi was able to obtain a strong position without doing the fundamental work. Branly patented the coherer but did not conceive of its use for wireless.<sup>33</sup> Lodge used it first for radio reception but did not feel that he had made an invention and did not apply for a patent. Marconi improved the coherer and was able to get the basic patents for its use in wireless.

Marconi's coherer, although practical for distances up to 100 or 200 miles, had the disadvantage of being "easily upset by the stray electric waves called 'atmospherics,' which are produced mostly by distant thunderstorms and also by any near-by electric sparks."<sup>34</sup> To overcome atmospheric interference, Marconi in 1902 developed the magnetic detector "based on a discovery by Lord Rutherford that very rapid electric currents can knock the

<sup>33</sup> Lodge first conceived of using the Branly coherer as a wireless detector and is credited with giving it the name "coherer." O. E. Dunlap, *Radio's 100 Men of Science* (New York, Harper, 1944), p. 76.

<sup>34</sup> Ambrose Fleming, *Memories of a Scientific Life* (London and Edinburgh, Marshall, Morgan and Scott, 1934), p. 139.

magnetic state out of an iron wire.”<sup>35</sup> This detector was “more certain in its action than the coherer but had the disadvantage that the signals could only be heard as sounds in a telephone and could not be recorded on a tape.”<sup>36</sup> For the succeeding ten years, however, the magnetic detector was standard receiving equipment on English and most other European vessels.<sup>37</sup>

The two inventions that were to prove of outstanding importance to the Marconi patent structure were the Lodge tuning patent<sup>38</sup> and the patent on the Fleming valve.

One of the major problems to be solved in the early days of wireless was how to make a receiver select messages from those that were sent out simultaneously from different stations. The pioneering work was done by Oliver Lodge, who through his studies of selective resonance, showed that, by adding an inductance coil to an antenna, selectivity was greatly increased. This was a very significant contribution, and Lodge applied for a patent on the method. Marconi realized that Lodge had discovered the basic principles of tuning. He set to work immediately to make Lodge’s method more practical in a number of ways, including the addition of what is known today as a tuning dial.<sup>39</sup> Marconi’s patent on tuning (British No. 7777, filed in 1900) became one of the most famous in wireless history. Marconi brought a series of successful suits against most of his early rivals on this patent; but in 1911 the prior Lodge patent was upheld against Marconi. It was then purchased by the Marconi company on condition that the Lodge-Muirhead syndicate,<sup>40</sup> which had been

<sup>35</sup> *Ibid.*

<sup>36</sup> *Ibid.*, p. 140.

<sup>37</sup> A. F. I Harlow, *Old Wires and New Waves* (New York, Appleton-Century, 1946), p. 448.

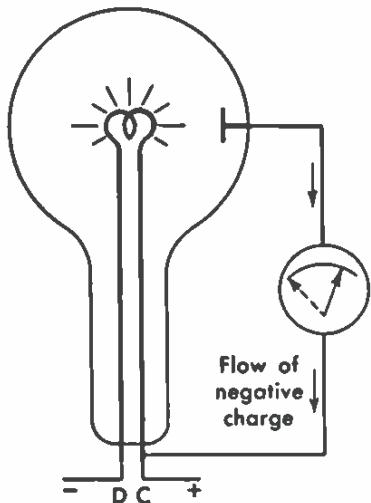
<sup>38</sup> U. S. Patent No. 609,154, application Feb. 1898, issued August, 1898. This was the only one of the three principal Marconi company patents which was completely upheld by the Supreme Court in 1943, when the Marconi four-circuit tuning patent was held invalid.

<sup>39</sup> Douglas Coe, *Marconi, Pioneer of Radio* (New York, J. Messner, Inc., 1943), p. 111.

<sup>40</sup> The Lodge-Muirhead Syndicate had been formed in 1901 with £50,000 capital. It was unable to obtain a commercial license in England, and was therefore forced to do business with Colonial governments, particularly in Burma and India. Colonel F. J. Davies testified before the House of Commons in 1907 that the Lodge-Muirhead sets had “given the most satisfactory results so far” in competition with Telefunken and Marconi. *Report to Select Committee, op. cit.*, p. 47.

formed to develop Lodge's radio patents, cease its operations.

The second most important patent in the Marconi structure was on the Fleming valve. Fleming's invention was declared by the courts to be basic to the whole vacuum-tube art,<sup>41</sup> and its history is therefore of particular importance. In 1883 Thomas Edison, investigating the blackening of lamps, had noticed that under certain conditions of vacuum and voltage a lamp would give off a blue glow. Experimenting, he found this to be caused by an unexplained current that flowed directly across the space between the two legs of the lamp filament. The flow took place in the opposite direction to the regular current passing through the filament—that is, from the cathode or negative terminal to the anode or positive terminal. Edison recorded his observations on this phenomenon but was not able to explain it. It became known as the "Edison Effect," and the inventor secured a patent on an "electrical indicator" based on the effect in October 1884.<sup>42</sup>



The Edison Effect. The current flows from the hot filament to a plate inside the bulb, causing an indication on the galvanometer when the plate is made positive. When the plate is connected to the negative wire, no current flows. (Courtesy Dunning and Paxton, *Matter, Energy, and Radiation*, McGraw-Hill)

From then on, the Edison Effect was studied in both its theoretical and practical aspects. Scientists linked this phenomenon with similar manifestations from other sources, such as x-rays. And in 1897 the British physicist, J. J. Thomson of the Cavendish Laboratory, published his theory of the electron, in which he suggested that atoms of a metal are made up of negative charges

<sup>41</sup> In 1943 the U.S. Supreme Court upheld a decision of the Court of Claims declaring that the Fleming patent was invalid. The patent, however, had long since expired and was not successfully challenged during its life. *Marconi vs. U.S.*, 320 U.S. 1.

<sup>42</sup> U.S. Patent No. 307,031.

imbedded in a sphere of positive charges. When a metallic electrode is heated to an extremely high temperature, these negative charges, or electrons, boil out of the metal and are drawn across to the anode. This electron flow, he thought, manifested itself in the blue glow of the Edison Effect.

Ambrose Fleming, who had been scientific adviser to the Edison Electric Light Company of London and who had seen Edison's experiments, conceived the idea of using a vacuum lamp of the Edison type as a detector for wireless signals. The ether waves sent out from a radio station are at such a high frequency that they are inaudible to an instrument like the telephone. To produce audible sounds in a wireless head phone, which was a standard method of reception in the early days, it was necessary that the signals be rectified—that is, passed through a device that allows the current to flow in one direction only and suppresses any flow in the other direction.<sup>43</sup>

Fleming decided to utilize the Edison Effect in a wireless valve. He constructed a vacuum tube with a cathode and an anode, and attached a battery to the cathode, enabling him to heat it to incandescence so that electrons would be continuously emitted. Fleming then inserted the tube in the aerial circuit of his receiver. The alternating character of an incoming wireless signal made the anode successively positive and negative. During the negative half of the signal wave, the anode repelled the electrons given off from the cathode, and no current flowed. But during the positive phase, the anode was positively charged, and drew the electrons across the tube, causing a flow of current that operated a telephone receiver or a recording device. Fleming's invention, patented in 1904, went automatically to the British Marconi company under his consulting contract.

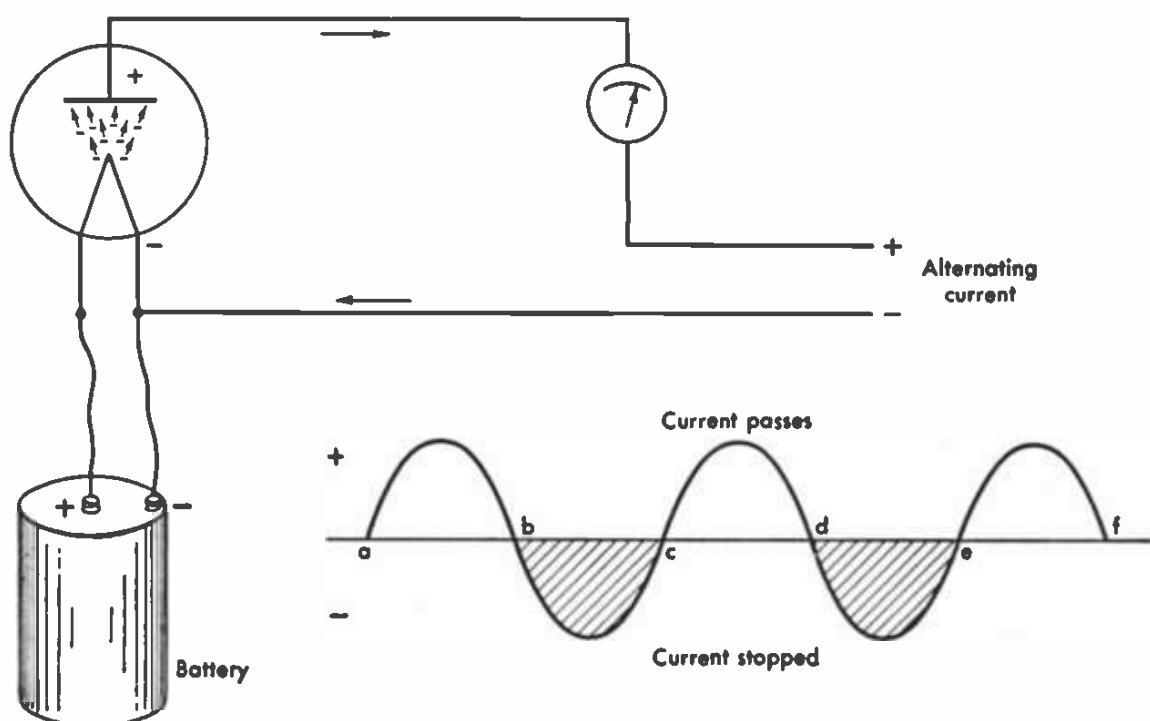
In its original form the Fleming two-element tube or diode was not as satisfactory<sup>44</sup> as the crystal detector which was invented about the same time. It was not until de Forest added the plate battery and grid control, and Arnold and Langmuir showed the

<sup>43</sup> Arnold *vs.* Langmuir, Interference No. 40,380, Brief on Behalf of Irving Langmuir, p. 25.

<sup>44</sup> In initial operation, the diodes were superior to crystal detectors, but they soon became unstable and erratic. They were, therefore, never really used in practical wireless telegraphy.

necessity of very high vacuum that the valve became the key-stone of modern radio communications.

Marconi himself made no important inventions after 1902. The character of his work changed from inventing to the initiation of research to be carried out by subordinates. Although he became increasingly involved as a promoter of his world-wide enterprises, he remained for many years the dominant *technical* figure in the company. He had considerable imagination about possible



Operation of a diode or two-element tube, showing a valve action which will allow passage of current in one direction only. (Courtesy Stokley, *Electrons in Action*, Whittlesey House)

new improvements in wireless telegraphy, and was primarily responsible for setting others to work on most of the problems that were investigated.

But he does not rank with Edison, Cartwright, Watt, Bell or de Forest in the originality of his technical contributions.

Taussig, in *Inventors and Money Makers*, concluded from a review of the lives of inventors that:

We are misled by the fact that the names of most inventors are associated with one device, at most two. Watt, with the steam engine, Cartwright, with the power loom and the combing machine, Fulton,

with the steamboat, Howe, with the sewing machine, Ericcson, with the screw propeller and the monitor, Bell, with the telephone, Edison, with the incandescent light and the moving picture. Their biographies show that they were constantly experimenting on all sorts of schemes, promising and unpromising; sometimes with money-making intent, sometimes in the spirit of scientific research, and sometimes merely in sport. Werner Siemens, one of the few who combined a strictly scientific temper with the genius for contrivance, began with the telegraph, proceeded to the metallurgy of iron and copper, closed with devotion to the field of pure science.<sup>45</sup>

This description does not fit Marconi. He devoted his life exclusively to the one purpose of perfecting and promoting wireless telegraphy and his inventions were entirely confined to that field.

### 3. Marconi as Research Director and Manager

Marconi surrounded himself from the beginning with a group of able technical assistants. In 1900 there were seventeen professional engineers in the Marconi company in England, many of whom later became well known in electrical engineering circles.<sup>46</sup> In addition, Marconi sought out some of the most promising university scientists who were interested in wireless and employed them as consultants, among them Lord Kelvin. Marconi was not afraid, as many inventors have been, of hiring men with greater technical competence than his own.

The selection as a consultant of Ambrose Fleming, who was then a promising young professor of electrical engineering at University College, London, illustrates Marconi's practice when special technical obstacles were met. With the apparatus used from 1896 to 1898, Marconi had found that, if he doubled the height of the aerial, the range of possible communication would be four times greater. But the practicable economic height of wooden masts for supporting the aerial was at that time believed to be about 200 feet. Marconi concluded that he would have to

<sup>45</sup> F. W. Taussig, *Inventors and Money Makers* (New York, Macmillan, 1915), pp. 22–23.

<sup>46</sup> This original group included Dr. W. H. Eccles, Dr. Erskine Murray, W. W. Bradfield, Andrew Gray, C. S. Franklin and H. J. Round. *Vyvyan, op. cit.*, p. 24.

design a transmitter of much greater power than had been used hitherto. Fleming, he learned, had gained considerable experience in the electric lighting field with extra-high tension alternating currents. He therefore appointed him as scientific adviser to the company.

In the United States the American Marconi company engaged Michael Pupin as a consultant for a number of years.<sup>47</sup> Pupin, a professor of physics at Columbia, was one of the leading contributors to electrical engineering development of the period.<sup>48</sup> His most important invention was that of the loading coil—of great importance in long-distance telephony. The connection with the Marconi company did not prove fruitful; but the selection of Pupin was characteristic of the company's high standards in searching for scientific assistance.

Marconi had considerably greater capacity for directing research than for managing a business. An early associate stated that he "detested routine business and legal conflicts."<sup>49</sup> The Marconi enterprises did not become a financial success until Godfrey Isaacs was appointed managing director in 1910. Marconi was enough of a salesman to interest William Preece in his work and to acquire the all-important contracts with the British Admiralty and Lloyd's. Yet much of the good will toward the young inventor was dissipated later by the company's tactics. The quarrel with Lloyd's, which resulted in a suit, could easily have been avoided. And in 1907, Sir William Preece, the erstwhile champion of Marconi, declared: "I have formed the opinion that the Marconi company is the worst managed company I have ever had anything to do with. . . . Its organization is chiefly indicated by the fact that they quarrel with everybody."<sup>50</sup>

As Marconi's friends and contemporaries declare that he had a very equable temperament and got along extremely well with his technical associates, this is difficult to explain. Apparently he had no intuitive sense of how to develop smooth business relations.

<sup>47</sup> *Electrical World*, June 6, 1903, p. 961.

<sup>48</sup> Pupin made a fortune from his inventions which he subsequently gave to Columbia University for science buildings.

<sup>49</sup> James C. H. Macbeth, quoted in Dunlap, *Marconi, the Man and His Wireless* (New York, Macmillan, 1937), pp. 204-205.

<sup>50</sup> *Report to Select Committee, op. cit.*, pp. 232-234.

This was, perhaps, because of his fervid interest in the technical phases of wireless. After several difficult business years, the directors of the company decided that they must bring in a man of exceptional promotional skill and influential connections to take charge of the broad business policy of the far-flung Marconi enterprises. Accordingly, in 1910, Godfrey Isaacs was appointed managing director. Isaacs was a brother of Rufus Reading, the Lord Chief Justice, and a close friend of Herbert Samuel, the British Postmaster-General. Such government connections were particularly important when it came to competing with Germany, which also was trying to develop a world-wide system of wireless communication. In South America and other countries, where International Marconi was expanding, British ambassadors were enlisted to help the company secure concessions. And when in 1912 the British Post Office decided to build a series of radio stations throughout the Empire, it gave the contract to the Marconi company.<sup>51</sup> (The Marconi company then began construction of the Imperial Chain on a spark basis, which was largely outmoded.)

Godfrey Isaacs, in the minds of those who knew the company well, became "the king-pin of the organization."<sup>52</sup> An associate described him as "the salesman of wireless with the business strategy and enthusiasm necessary to promote such a radically new communication system. He revelled in acquiring telephone and electrical instrument companies to link them as subsidiaries of wireless. Marconi entrusted the business end of wireless and its promotion to Mr. Isaacs, who presided at the company's meetings and usually at public functions."<sup>53</sup>

The research and advanced engineering development for the Marconi enterprises was conducted primarily in England.<sup>54</sup> The company was sufficiently well financed, so that it was able to sup-

<sup>51</sup> Marconi stock jumped from £2 per share in August, 1911, to £9 in April, 1912—less than a month after the government accepted the formal Marconi tender. The contract later proved lucrative in an unexpected fashion. The post office cancelled it during the war and was sued for damages. The courts awarded the Marconi company £600,000 for this breach. Dunlap, *op. cit.*, p. 207.

<sup>52</sup> James C. H. Macbeth, early member of the company, quoted in Dunlap, *op. cit.*, pp. 204, 205.

<sup>53</sup> *Ibid.*

<sup>54</sup> The American Marconi company, however, did have some very competent engineers, including Roy Weagant, Ralph Langley and Harold Beverage.

port a research organization from the beginning. This remained on a much more modest scale than in companies like General Electric and American Telephone and Telegraph.

Marconi's principal weakness as a director of research was that he emphasized the perfecting of existing methods instead of reaching out for radically new discoveries in wireless. Although this may occur in any research organization, there is more danger of it where the director takes a restricted scientific view of the functions of his company. Marconi's intense drive for the rapid commercialization of wireless produced a number of blind spots, the most serious of which was his failure to visualize continuous-wave operation in transatlantic working, and in turn the significance of radio *telephony*. No one, of course, foresaw the development of the radio broadcasting industry, but there were many of Marconi's contemporary inventors who believed in the wireless telephone. Marconi did not share their optimism. He thought that the Morse code was adequate for communication with ships and for transoceanic messages and saw no clear need for voice transmission. Since his approach was pragmatic, he was not interested in the scientific investigation of a field whose commercial possibilities seemed remote. This was unfortunate both for the Marconi company and for the advancement of the art. The early experimentation with the radio telephone was left almost entirely to Marconi's American rivals, Lee de Forest and Reginald Fessenden, neither of whom had at his disposal financial resources or engineering skill comparable to the Marconi enterprises.

On the other hand, within the limitations of spark wireless telegraphy, Marconi's research organization made substantial advances—by attaining greater distances, by achieving better tuning and by partially overcoming static and interference.

In the early years, interference from other stations was so serious that "there were only two sure ways of getting a message through: wait till no one else happened to be sending, or boost up the power of your transmitter in an attempt to drown out the other fellow and allow your own signal to be deciphered by sheer brute power. The second method was the usual one."<sup>55</sup>

<sup>55</sup> G. H. Clark, unpublished ms., *John Stone Stone*, p. 79.

Marconi's attempts to eliminate interference centered in the development and improvement of the coupled circuit.<sup>56</sup> His controlling patent on the coupled circuit (the 7777 British patent) was issued in 1900, but variations in closer or looser coupling were made by the company for many years afterward in attempts to lengthen the train of waves and to increase selectivity. Marconi himself continually encouraged his research engineers to make improvements in the sharpness of tuning.<sup>57</sup>

Another important advance in spark telegraphy was duplex working. Until 1913 it was the practice to have transmitting and receiving aerials on one site, the transmitter being stopped at intervals and the receiver switched on so that the distant station could acknowledge receipt or ask for repetitions.<sup>58</sup> As a result, each plant was in use only half the time. This was very difficult to correct because of the lion-and-lamb characteristic of a transmitter and a receiver. The transmitter was brutally powerful in contrast with its receiver, the energy received being only an infinitesimal part of that sent. Detectors of the period were notoriously delicate and were readily upset by any surge of high power.

Marconi ultimately evolved a plan of duplex working, first introduced on the Ireland–Canada link, by which the sending and receiving stations were separated by a number of miles. Two directive aerials were employed for each receiver, one getting optimum reception from the remote station, the other from the local transmitter. The transatlantic aerial received the distant signal, plus a local interfering signal, while the other received only the local station. When the two aerials were coupled in opposition, the local signals were balanced out, leaving a transatlantic signal free from interference.

Even these ingenious measures were not sufficient to provide reliable transatlantic wireless communication. Spark telegraphy

<sup>56</sup> In this circuit the spark gap was not directly connected in series with the antenna, but was placed in an "exciting" circuit of its own.

<sup>57</sup> Vyvyan, *op. cit.*, p. 56. In 1911 H. J. Round invented a balanced crystal circuit for reception. He employed two crystals working in opposition, and so set that one was sensitive to the signal whereas the other only operated when a disturbance exceeded the value to which it had been adjusted. This gave relief to the operator, and yet produced stronger signals.

<sup>58</sup> *ibid.*, p. 58.

was inevitably doomed by the rapid progress of continuous-wave transmission, and in this development Marconi's research organization did not participate. By 1916 the Poulsen arc and the Fessenden-Alexanderson alternator, both of which produced continuous waves, had been improved to a point where they were more reliable than spark apparatus. The patents on the Poulsen arc were held by enterprises that were competing with Marconi. The Marconi company tried to buy rights to the alternator from General Electric but was unable to reach an agreement before the war terminated negotiations.

Marconi did develop a semi-continuous "timed disc" transmitting apparatus that was installed at Carnarvon in June 1916. It was technically a success, though so noisy that it was known as the "Rock Crusher." The first wireless message sent directly from England to Australia was transmitted by this apparatus.<sup>59</sup> In the meantime, the Germans in 1914 had inaugurated machine-generated continuous-wave transmission across the North Atlantic. And three years later General Electric, using the Alexanderson high-frequency alternator, perfected a system of continuous-wave telegraphy superior to any other existing apparatus for long-distance communication.<sup>60</sup>

Marconi engineers played no pioneer roles in the development of the three-element vacuum tube, the feedback circuit and the heterodyne. These were the most revolutionary advances in the science of wireless communications between 1900 and the first World War. Although Marconi's research organization made some contributions beyond the two-element tube of Fleming, they were, from a patent point of view, "too little and too late."<sup>61</sup>

The most significant contribution of Marconi engineers after

<sup>59</sup> Vyvyan, *op. cit.*, pp. 65-66.

<sup>60</sup> Two other companies were competing with Marconi for transatlantic traffic—Telefunken with its station at Sayville, Long Island, communicating with Nauen, Germany; and a station at Tuckerton, New Jersey, communicating with Eilvese, Germany. Tuckerton, using the alternator of Dr. Rudolph Goldschmidt, was the first American high-power station to use machine-generated continuous waves.

<sup>61</sup> C. S. Franklin of British Marconi devised a feedback circuit which greatly increased the amplification powers of receiving tubes, but priority of invention in the United States was awarded successively to Armstrong and de Forest. H. J. Round of British Marconi also did some early experimental work on the oscillatory feedback.

the invention of the Fleming valve was the development of beam transmission and short-wave propagation. In the progress of wireless telegraphy since Hertz's time, experiments had indicated that increasing the wave-length to as much as 20,000 meters produced steadily better results for *long distance* communication. Radio engineers had assumed, therefore, that very short waves would simply not carry over long distances, although Hertz, using concave mirrors, had demonstrated that very short waves could be focussed in a beam, obeying the ordinary optical laws of reflection.

In 1916 Marconi asked Franklin to re-explore the use of the short waves which had been the basis for the original experiments of Hertz.

I could not help feeling [Marconi said] that we had perhaps got rather into a rut by confining practically all our researches and tests to waves of some thousands of feet in length.<sup>62</sup>

Marconi was concerned with the military problem of sending messages which would not be readily intercepted by the enemy. Franklin, using vacuum-tube techniques, duplicated Hertz's experiments, and carried them through to a carefully engineered system of beam transmission. It came as a surprise to everyone, when, after the war, Franklin in England, Frank Conrad of the Westinghouse company, and various groups of amateurs independently found that they could communicate over very long distances by the use of short waves. Marconi and Franklin persisted in their tests, and reached the conclusion that a commercial system of short-wave beam stations throughout the British Empire would give much more reliable and effective service than was possible with long-wave apparatus. The Marconi company succeeded in 1924 in securing a contract with the British Post Office to erect such stations in Canada, India, South Africa and Australia.

These installations proved extremely successful and forced all wireless organizations to enter this new field of development.<sup>63</sup> With the inauguration of beam services, the radio began for the

<sup>62</sup> G. Marconi, "Radio Telegraphy," *Proc. I.R.E.*, Vol. 10, No. 4, August 1922, p. 215.

<sup>63</sup> Vyvyan, *op. cit.*, p. 92.

first time to compete seriously with the cable in transoceanic communications.

Marconi himself continued throughout his life to experiment with wireless. A large portion of his time from the years 1919 to 1934 was spent on board the yacht *Elettra*—which was his research laboratory at that time—testing and perfecting new types of apparatus. Most of this work could be described as advanced engineering development. He was concerned with “next year’s model,” rather than with a radically new approach.

Sir Ambrose Fleming may have had Marconi in mind when he wrote:

Invention consists in overcoming the practical difficulties of the new advance, not merely talking or writing about the new thing, but in *doing it*, and doing it so that those who come after have had real obstacles cleared out of their way, and have a process or appliance at their disposal which was not there before the inventor entered the field. In most cases, however, the removal of the obstacles which block the way is not entirely the work of one person. The fort is captured only after a series of attacks, each conducted under a different leader. In these cases the inventor who breaks down the last obstruction or leads the final assault is more particularly associated in the public mind with the victory than are his predecessors, though his intrinsic contribution may not actually be of great importance.<sup>64</sup>

Yet, despite his limitations, Marconi was truly the midwife of radio. Hertz’s discoveries lay in embryo, as it were, for nearly ten years, unheeded by entrepreneurs and inventors alike, a source of academic interest only. It required a man of exceptional vision to seize upon these scientific discoveries, relate them to an imperative need and translate them into a workable and effective method of communication.

Besides Marconi’s personal capacities as an inventor and more particularly as an innovator, the birth of wireless was abetted by two fortuitous circumstances. The first of these was that Marconi could afford, in the literal sense, to spend time and money on experiments. No economic pressure forced him to abandon his deep-seated convictions that wireless would work. Marconi was once asked what he would have done had he been very poor. “In

<sup>64</sup> J. Ambrose Fleming, *Principles of Electric Wave Telegraphy* (London, Longmans, Green, 1906).

these circumstances," he replied, "I do not know whether I should have invented anything at all. If so, I am not at all sure I should have persevered."<sup>65</sup>

The other adventitious circumstance was Marconi's introduction in England. Had he remained in Italy, it is probable that he would eventually have abandoned his ideas for lack of stimulation, or that they would have been slow to develop because of the absence of a ready market in that country. The warm welcome accorded Marconi by British authorities and the active interest in a device which would strengthen England's maritime "life-line of Empire," gave him a sympathetic environment and a motivating drive that was of paramount importance.

<sup>65</sup> Jacot and Collier, *op. cit.*, p. 117. Cf. Edward Gibbon, "Wretched is the author and wretched will be the work where daily diligence is stimulated by daily hunger." *Autobiography* (New York, Fred De Fau and Company, 1907), p. 248.